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ABSTRACT

The effects of pure tone stimulation on ongoing motor activity of infants 1 to 4 days of age were studied using a passive, contactless monitoring device. Stimuli were pure tone bursts of 0.5, 1, and 4 kHz presented free field at an approximate level of 70 dB A. Signal trials consisted of 500 ms tone bursts, with rise/fall time equal to 10 ms, and with 500 ms silent intervals between bursts in a 10 s pulse train. No-signal trials were also 10 s in duration, but no tone burst occurred. Probability of a no-signal trial equaled 0.25. Trials started when the baby was active at a criterion level for at least 10 s. Activity was measured as the variance of the instantaneous output of the monitoring device. The probability of increase or maintenance of pre-trial activity was significantly higher on signal trials than on no-signal trials, especially for 0.5 and 4 kHz tone bursts. This effect may reflect a temporary sound-induced change in the infant's cyclic motility, and could afford a means for testing hearing in newborns. (Author)

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Newborn's Motor Response to Pure-Tone Stimulation

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Newborns' Motor Response to Pure-Tone Stimulation

NEWBORNS' MOTOR RESPONSE TO PURE-TONE STIMULATION. Lynne Werner Olsho, Jay Gillenwater.

Abstract

The effects of pure tone stimulation on ongoing motor activity of infants (aged 1 to 4 days) was studied using a passive, contactless monitoring device. Stimuli were pure tone bursts of 0.5, 1, and 4 kHz presented free field at an approximate level of 70 dB A. Signal trials consisted of 500 ms tone bursts, with rise/fall time equal to 10 ms, and with 500 ms silent intervals between bursts in a 10 s pulse train. No-signal trials were also 10 s in duration, but no tone bursts occurred. Probability of a no-signal trial equaled 0.25. Trials started when the baby was active at a criterion level for at least 10 s. Activity was measured as the variance of the instantaneous output of the monitoring device. The probability of an increase or maintenance of pre-trial activity was significantly higher on signal trials than on no-signal trials, especially for 0.5 and 4 kHz tone bursts. This effect may reflect a temporary sound- induced change in the infant's cyclic motility, and could afford a means for testing hearing in newborns.

Introduction

The need for effective means to study early hearing development in newborns is widely recognized. The methods utilized to date for the identification of infants with severe hearing loss have not proven useful in the study of infant perceptual development, due to limited response range, state dependency, and other methodological constraints.

This poster presents preliminary results of a study into the effects of sound stimulation on patterns of motor activity in newborn infants. Robertson (1982, 1986) described the motor activity of infants as a cyclic phenomenon with a period of

approximately 1 minute, and constant magnitude, frequency and variance for each infant. These characteristics are for the most part, state-independent, first appearing during the 3rd fetal trimester and lasting until the 5th week postpartum. Thus, cyclic activity might provide a stable background against which responses to stimulation could be identified.

Methods

Subjects. Thirteen infants, ranging in age from 19 to 101 h (X = 46.5 h) from the University of Virginia Medical Center Newborn Nursery were tested. Only infants with 1 and 5 minute Apgar scores of 8 or better, weight > 1500 gm, uncomplicated pregnancies and deliveries and no family history of hearing loss, as determined from medical records, were included. Nine infants were used in the final sample. Four babies were excluded because they did not complete enough trials to make data analysis meaningful.

Stimuli and apparatus. Testing was performed in an untreated room (ambient noise level about 50 dB A) located next to the nursery. Free field pure tone stimuli were presented at .5, 1, and 4 kHz, at a level of about 70 dB A, via a 3-inch speaker located in front of the infant, 45 degrees to the left and slightly above ear level. Signal level was measured at the approximate location of the infant's head in the bassinet, in an octave band centered around the test frequency. Signal trials consisted of 500-ms repeating tone bursts with 500-ms silent intervals between bursts. No-signal trials were of equal duration but no sound was presented. The infant lay in a supine position in a bassinet, and wore a diaper and shirt. The child was occasionally draped with a receiving blanket. All subjects were tested in the early afternoon at least 1 h, but no more than 3 h, since the last feeding.

The passive monitor was placed over the mattress of the bassinet and covered with a receiving blanket (Fig. 1A). The monitor produces a continuous voltage, the amplitude of which varies as the infant moves. The signals were differentially amplified (Grass P15 or Tektronix 5A21N) and recorded on a 4 channel FM tape. A second channel recorded trigger pulses generated synchronously with sound presentation (Sage Microprocessor).

A trial was initiated once the infant was in a quiet, alert state and had maintained a criterion level of activity for 10 s, as judged by a second experimenter monitoring the infant's activity on an oscilloscope. Intertrial interval was at least 10 s in duration and the average test session lasted 17.5 minutes, excluding stops for fussiness or equipment problems. Testing was terminated when the infant became fussy or had fallen asleep.

Data Analysis. The output of the monitor and the trigger pulses indicating signal presentations were simultaneously digitized off line using a Data Translation 2701A board mounted in an AT&T 6300 PC (sampling rate = 150 samples/s) (Figure 1B). The variance in monitor output, the measure of activity, for a 10 s baseline period was compared to the variance in each of 8, 1 s-intervals during sound presentation by F-ratio. Each 1-s interval was then coded as an increase, a decrease, or no change in activity, using a criterion significance level of $p < 0.05$ (Table 1). Since no sound was presented to the infants during no signal trials, the probability of observing each of these events on no- signal trials is our best estimate of the infant's spontaneous changes in activity over a 20-s period. If the presentation of a sound did not affect the infant's activity, then the observed frequency of a given response type on a signal trial should be predicted by the probability of that response on no-signal trials. Thus, we calculated the binomial probability for each response on signal trials, estimating the a priori probability of each response, P, from the proportion of responses on no-signal trials in that infant's data. Because the 8, 1-s intervals on each no-signal trial were very similar in P values, we combined intervals to estimate the final value of P. This also helped to avoid the problem of finding no responses of a given type in a certain interval, resulting in P = 0. In cases where no response of a given type was found in any of the intervals, P values were approximated by 1/total number of intervals. Thus, an infant who only showed decreases from baseline activity levels for each interval in 5 possible no-signal trials, would have an assigned P value of $1/(8*5) = .025$ in tests for the significance of increases in activity levels. This was considered a conservative approach, since the actual response probability could have been much smaller.

Results

Of the nine infants completing sufficient trials, seven showed a significantly ($p < 0.05$) different pattern of activity during at least one interval on signal trials compared to no- signal trials. The other two showed near-significant differences ($p < .09$) in several intervals. The most pronounced effect was a maintenance or increase in activity (+/0) at 0.5 and 4 kHz (Table 2). In other words, the most frequently observed difference between signal and no-signal trials was that infants were significantly more likely to show an increase or maintenance of activity during at least one interval on signal trials.
There were a few infants, however, who showed a significant decrease in activity on signal trials.

Examination of responses across the 8, 1-s intervals revealed no readily apparent temporal distribution of responses within trials for the infants who demonstrated an increase or no change response. For the three infants who showed significant or marginally significant decreases in activity in response to sound, the responses always occurred during the last 4 intervals. Although this observation is based on very few infants and few responses, other evidence suggests differences between these two groups of infants.

First, the infants who showed activity decreases had much lower P values for activity decreases on no-signal trials than the other infants (Table 3). In other words, the infants who showed activity decreases in response to sound, showed a tendency to continue to increase or maintain their activity after a no- signal trial started. Moreover, the amount of activity on no- signal trials for the "decrease responders" tended to be higher relative to the amouunt of activity on other trials. This suggests that the newborns who inhibited activity on signal trials may have had somewhat longer duration motility cycles than the other infants. Trials starting at a fixed time into a period of activity, therefore, caught these infants at a point when activity was still on the rise. For the infants who showed activity facilitation in response to sound, it was clear that the peak of the activity cycle had passed, since the probability of an activity decrease for these infants on no-signal trials was so high.

These observations suggest, further, that timing of trial onset will be a critical variable to control in future development of this technique. It is likely that on-line monitoring of responses and the development of algorithms to adapt trial onsets to the individual infant's response pattern will greatly increase the number of infants in whom responses are observed and the consistency with which responses are seen for a given infant.

Surprisingly, only a few significant intervals were found in the 1000 Hz condition. This was an unexpected finding, since responses were observed at 4000 Hz and responses to low to middle frequency sounds have generally been observed prior to those to high frequencies in other mammals and in earlier studies of human newborns (reviewed by Rubel, 1978). However, the possibility of idiosyncracies in the spectrum of ambient noise and possible variations in the actual levels of the tones arriving at the newborn's inner ear make any conclusions about sensitivity at 1000 Hz difficult at this point.

Discussion

The spontaneous cyclic motility of newborn infants provides a stable baseline against which changes in activity due to sound presentation can be observed. The fact that these changes in activity can be observed in a large proportion of infants when moderate sound intensities are employed suggests that this technique may be extremely useful in the study of early human audition. Our success in acutally estimating infant thresholds will be dependent on several factors. As mentioned above, it appears to be important to accurately time stimulus presentations with respect to the infant's motility cycle. In addition, we chose baseline, trial, response interval, and interstimulus interval durations rather arbitrarily in this preliminary study. Although the significant response for most infants suggests we were close, additional analyses may indicate that somewhat different temporal parameters would improve our "hit" rate.
Here we only included infants who were in an awake, alert state. Many authors (e.g., Simmons & Russ, 1974) have noted that the amount of infant activity is dependent on state. However, Robertson (1986) reports that the period of cyclic motility is state independent. If the ability of sound to modulate activity is unaltered by state, then a measure based on alterations in the timing of activity, rather than the amount of activity, may prove to be a sensitive indicator of hearing even in sleeping infants.

Conclusions

1) Newborns' activity during presentations of pure tones is significantly different from activity when no tone is presented, when moderate sound intensities are used.

2) This effect is most prominently seen as an increase or maintenance over baseline activity.

3) Activity changes were most pronounced with sound stimulation at 0.5 and 4 kHz.

4) Individual differences in cyclic motility period may affect both the nature of the response observed and the likelihood of observing a response when sound onset occurs at a fixed time after activity begins.

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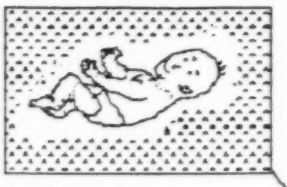
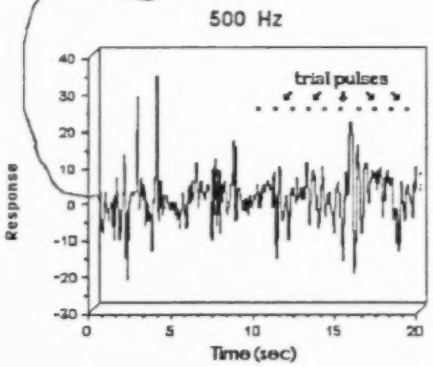


FIGURE 1A

FIGURE 1B



Digitize

-1 -1 1 0 0 1 2 3 3 2 0 -2 -2 0 .....

Calculate variance
9/trial

	Intervals							
Baseline	1	2	3	4	5	6	7	8
.07	1.6	.91	.61	.65	6.9	6.0	3.1	.70

compute f-ratio
(8/trial; Interval/baseline)

Intervals							
1	2	3	4	5	6	7	8
.30	.04	.02	.02	3.4	3.2	2.5	.03

recoding
8/trial

Intervals							
1	2	3	4	5	6	7	8
0	-	-	-	+	+	+	-

Count for each response type

'+' response

TYPE	Intervals							
	1	2	3	4	5	6	7	8
.5 KHz	2	2	2	3	4	3	3	2
1 KHz	0	1	0	1	1	1	1	1
4 KHz	2	1	2	2	2	2	3	3
no signal	0	0	0	1	1	0	0	0

] a priori p('+')

calculate binomial probability for each response type

'+' response

TYPE	Intervals							
	1	2	3	4	5	6	7	8
.5 KHz	•	-	•	•	•	-	•	•
1 KHz	-	-	-	-	-	-	-	-
4 KHz	•	-	-	-	•	•	•	•

* $p < .05$

FIGURE 1A: INFANT RESTING ON PASSIVE, CONTACTLESS MONITOR.

FIGURE 1B: WAVEFORM GENERATED DURING ONE TEST TRIAL. THE DATA WERE THEN ANALYZED FOR SIGNIFICANT CHANGES IN ACTIVITY AS DIAGRAMED ABOVE.

Table 1

trial type	interval	recoding
no signal	7	--------
	9	--------
	14	---++0--
	19	--------
	20	--------
500	1	+++++++
	4	+0++++++
	10	0---+++-
	12	--------
	17	---0----
	22	---++-0-
1000	4	-+0++++++
	5	--------
	8	--------
	13	--------
	16	--------
	23	--------
	24	-0------
4000	3	--------
	6	--------
	11	+++++++
	15	+0++++++
	18	--------
	21	------++
	25	--------

Table 1: Recoded data for one subject. Each interval is sorted to its appropriate trial type.

Table 2

Interval

Frequency	1	2	3	4	5	6	7	8
500	2	0	4	5	5	1	2	5
1000	1	0	0	0	2	1	0	1
4000	3	3	2	1	5	5	7	4

Table 2: Number of infants showing significant changes in activity for each of the 8 , 1s intervals (n = 9 ; $p < .05$).

Table 3

Chance probabilities (decrease)

	subject	.5K	1K	4K
Positive responders	13	.925	.925	.925
	10	.875	.875	.875
	09	.958	.958	.958
	08	.958	.958	.958
	07	.821	.821	.821
	12	.958	.958	.958
Negative responders	02	.525	.525	.525
	04	.583	.583	.583
	11	.541	.541	.541

Table 3: Chance probabilities of a decrease in activity for all infants used in this study